

CLAIMS

I/We claim:

1. An instrument, comprising:
an elongated body having a distal section configured to be passed through a passageway in a human; and
a magnetic marker having a transponder at the distal section of the flexible member, the transponder having a circuit configured to be energized by a wirelessly transmitted magnetic excitation energy and to wirelessly transmit a magnetic location signal in response to the excitation energy.
2. The instrument of claim 1 wherein the distal section of the body is a flexible member having a wall with an inner surface defining the lumen, an outer surface, and a recess in the outer surface, and wherein at least a portion of the marker is in the recess.
3. The instrument of claim 1 wherein the distal section of the body is a flexible member having a wall with an inner surface defining the lumen, an outer surface, and a hole through the wall from the outer surface to the inner surface, and wherein at least a portion of the marker is in the hole.
4. The instrument of claim 1 wherein the transponder comprises an alternating magnetic circuit having a ferrite core and a coil with a plurality of windings around the ferrite core.
5. The instrument of claim 1 wherein the transponder comprises a ferrite core and a coil around the ferrite core, and wherein the marker further comprises a capsule encasing the transponder, the capsule having a longitudinal axis and a cross-sectional dimension normal to the longitudinal axis of not greater than 2 mm.

6. The instrument of claim 1 wherein the body further comprises a distal section having a rigid first portion and second portion distally from the first portion; the marker comprises a first marker at one location of the rigid first portion; and the instrument further comprises a second marker spaced apart from the first marker at another location of the rigid first portion.

7. The instrument of claim 1 wherein the marker comprises a capsule and an alternating magnetic circuit in the capsule, and wherein the marker has a radiographic centroid and the alternating magnetic circuit has a magnetic centroid at least approximately coincident with the radiographic centroid.

8. The instrument of claim 1 wherein the transponder comprises an alternating magnetic circuit having a ferrite core and a coil having a plurality of windings around the core, and wherein the marker further comprises an imaging element such that the marker has a radiographic centroid and the alternating magnetic circuit has a magnetic centroid at least approximately coincident with the radiographic centroid.

9. The instrument of claim 1 wherein the marker comprises an alternating magnetic circuit having a ferrite core extending along a longitudinal axis, a coil having a plurality of windings around the ferrite core, and a capsule encasing the ferrite core and the coil, and wherein the ferrite core has a maximum cross-sectional dimension normal to the longitudinal axis of not greater than 0.7 mm and the capsule has a maximum cross-sectional dimension normal to the longitudinal axis of not greater than approximately 2 mm.

10. The instrument of claim 1 wherein:
the distal section of the flexible member has a wall with an inner surface defining the lumen and an outer surface; and
the transponder comprises a tubular ferrite core having an inner bore and a coil having a plurality of windings around the tubular ferrite core, and wherein a portion of the outer surface of the distal section is in the bore of the tubular ferrite core.

11. An instrument for insertion into a passageway of a human, comprising:
a catheter including an elongated flexible tube having a proximal section, a distal section and a lumen through at least the distal section;
a tool in the lumen of the distal section of the catheter; and
a marker having a magnetic transponder including a circuit configured to be energized by a wirelessly transmitted pulsed magnetic field and to wirelessly transmit a pulsed magnetic location signal in response to the pulsed magnetic field, wherein the marker is attached to the catheter and/or the tool.
12. The instrument of claim 11 wherein the distal section of the tube has a wall with an inner surface defining the lumen, an outer surface, and a recess in the outer surface, and wherein at least a portion of the marker is in the recess.
13. The instrument of claim 11 wherein the distal section of the tube has a wall with an inner surface defining the lumen, an outer surface, and a hole through the wall from the outer surface to the inner surface, and wherein at least a portion of the marker is in the hole.
14. The instrument of claim 11 wherein the transponder comprises an alternating magnetic circuit having a ferrite core and a coil with a plurality of windings around the ferrite core.
15. The instrument of claim 11 wherein the transponder comprises a ferrite core and a coil around the ferrite core, and wherein the marker further comprises a capsule encasing the transponder, the capsule having a longitudinal axis and a cross-sectional dimension normal to the longitudinal axis of not greater than 2 mm.
16. The instrument of claim 11 wherein the marker further comprises a capsule and the transponder comprises an alternating magnetic circuit within the capsule, and wherein the transponder is not electrically coupled to external leads outside the capsule.

17. The instrument of claim 11 wherein the marker comprises a capsule and an alternating magnetic circuit in the capsule, and wherein the marker has a radiographic centroid and the alternating magnetic circuit has a magnetic centroid at least approximately coincident with the radiographic centroid.

18. The instrument of claim 11 wherein the marker comprises an alternating magnetic circuit having a ferrite core, a coil having a plurality of windings around the core, and an imaging element, and wherein the marker has a radiographic centroid and the alternating magnetic circuit has a magnetic centroid at least approximately coincident with the radiographic centroid.

19. The instrument of claim 11 wherein the marker comprises an alternating magnetic circuit having a ferrite core extending along a longitudinal axis, a coil having a plurality of windings around the ferrite core, and a capsule encasing the ferrite core and the coil, and wherein the ferrite core has a maximum cross-sectional dimension normal to the longitudinal axis of not greater than 0.7 mm and the capsule has a maximum cross-sectional dimension normal to the longitudinal axis of not greater than approximately 2 mm.

20. The instrument of claim 11 wherein:
the distal section of the tube has a wall with an inner surface defining the lumen and an outer surface; and
the transponder comprises a tubular ferrite core having an inner bore and a coil having a plurality of windings around the tubular ferrite core, and wherein a portion of the outer surface of the distal section is in the bore of the tubular ferrite core.

21. The instrument of claim 11 wherein the tool comprises an ablation device.

22. The instrument of claim 11 wherein the tool comprises an RF transmitter.

23. The instrument of claim 11 wherein the tool comprises an implantable electrode that is detachable from the catheter and the marker is attached to the electrode.

24. The instrument of claim 11 wherein the tool comprises an ultrasonic actuator.

25. A system for tracking an instrument in a patient, comprising:

a catheter including an elongated flexible tube having a distal section configured to be passed through a passageway in a human and a magnetic marker having a transponder at the distal section of the tube, wherein the transponder has a circuit configured to be energized by a wirelessly transmitted pulsed magnetic field and to wirelessly transmit a pulsed magnetic location signal in response to the pulsed magnetic field; and

an excitation source comprising an energy storage device, a source coil, and a switching network coupled to the energy storage device and the source coil, the source coil being configured to wirelessly transmit the pulsed magnetic field to energize the transponder, and the switching network being configured to alternately transfer (a) stored energy from the energy storage device to the source coil and (b) energy in the source coil back to the energy storage device.

26. The system of claim 25 wherein the switching network comprises an H-bridge switch.

27. The system of claim 25 wherein the switching network is configured to have a first on position in which the stored energy is transferred from the energy storage device to the source coil and a second on position in which energy in the source coil is transferred back to the energy storage device.

28. The system of claim 27 wherein the first on position has a first polarity and the second on position has a second polarity opposite the first polarity.

29. The system of claim 25 wherein the source coil comprises an array having a plurality of coplanar source coils.

30. The system of claim 29 wherein the switching network is configured to selectively energize the coplanar source coils to change a spatial configuration of the pulsed magnetic field.

31. The system of claim 25 wherein the distal section of the tube has a wall with an inner surface defining the lumen, an outer surface, and a recess in the outer surface, and wherein at least a portion of the marker is in the recess.

32. The system of claim 25 wherein the distal section of the tube has a wall with an inner surface defining the lumen, an outer surface, and a hole through the wall from the outer surface to the inner surface, and wherein at least a portion of the marker is in the hole.

33. The system of claim 25 wherein the transponder comprises an alternating magnetic circuit having a ferrite core and a coil with a plurality of windings around the ferrite core.

34. The system of claim 25 wherein the transponder comprises a ferrite core and a coil around the ferrite core, and wherein the marker further comprises a capsule encasing the transponder, the capsule having a longitudinal axis and a cross-sectional dimension normal to the longitudinal axis of not greater than 2 mm.

35. The system of claim 25 wherein the marker further comprises a capsule and the transponder comprises an alternating magnetic circuit within the capsule, and wherein the transponder is not electrically coupled to external leads outside the capsule.

36. The system of claim 25 wherein the marker comprises a capsule and an alternating magnetic circuit in the capsule, and wherein the marker has a

radiographic centroid and the alternating magnetic circuit has a magnetic centroid at least approximately coincident with the radiographic centroid.

37. The system of claim 25 wherein the marker comprises an alternating magnetic circuit having a ferrite core, a coil having a plurality of windings around the core, and an imaging element, and wherein the marker has a radiographic centroid and the alternating magnetic circuit has a magnetic centroid at least approximately coincident with the radiographic centroid.

38. The system of claim 25 wherein the marker comprises an alternating magnetic circuit having a ferrite core extending along a longitudinal axis, a coil having a plurality of windings around the ferrite core, and a capsule encasing the ferrite core and the coil, and wherein the ferrite core has a maximum cross-sectional dimension normal to the longitudinal axis of not greater than 0.7 mm and the capsule has a maximum cross-sectional dimension normal to the longitudinal axis of not greater than approximately 2 mm.

39. The system of claim 25 wherein:

the distal section of the tube has a wall with an inner surface defining the lumen and an outer surface; and

the transponder comprises a tubular ferrite core having an inner bore and a coil having a plurality of windings around the tubular ferrite core, and wherein a portion of the outer surface of the distal section is in the bore of the tubular ferrite core.

40. A system for tracking an instrument through a vessel in a human, comprising:

a catheter including an elongated flexible tube having a distal section configured to be passed through a passageway in a human and a magnetic marker having a transponder at the distal section of the tube, wherein the transponder has a circuit configured to be energized by a wirelessly transmitted pulsed magnetic field and to wirelessly transmit

a pulsed magnetic location signal in response to the pulsed magnetic field; and

a sensor assembly comprising a support member and a plurality of field sensors carried by the support member, the field sensors being at least substantially locally planar relative to one another to sense the pulsed magnetic location signal from the transponder.

41. The system of claim 40 wherein the field sensors are responsive only to field components of the pulsed magnetic location signal normal to individual field sensors.

42. The system of claim 40 wherein the field sensors are arranged in an array occupying an area having a maximum dimension of approximately 100% to 300% of a predetermined sensing distance between the marker and the sensing array.

43. The system of claim 40 wherein the distal section of the tube has a wall with an inner surface defining the lumen, an outer surface, and a recess in the outer surface, and wherein at least a portion of the marker is in the recess.

44. The system of claim 40 wherein the distal section of the tube has a wall with an inner surface defining the lumen, an outer surface, and a hole through the wall from the outer surface to the inner surface, and wherein at least a portion of the marker is in the hole.

45. The system of claim 40 wherein the transponder comprises an alternating magnetic circuit having a ferrite core and a coil with a plurality of windings around the ferrite core.

46. The system of claim 40 wherein the transponder comprises a ferrite core and a coil around the ferrite core, and wherein the marker further comprises a capsule encasing the transponder, the capsule having a longitudinal axis and a cross-sectional dimension normal to the longitudinal axis of not greater than 2 mm.

47. The system of claim 40 wherein the marker further comprises a capsule and the transponder comprises an alternating magnetic circuit within the capsule, and wherein the transponder is not electrically coupled to external leads outside the capsule.

48. The system of claim 40 wherein the marker comprises a capsule and an alternating magnetic circuit in the capsule, and wherein the marker has a radiographic centroid and the alternating magnetic circuit has a magnetic centroid at least approximately coincident with the radiographic centroid.

49. The system of claim 40 wherein the marker comprises an alternating magnetic circuit having a ferrite core, a coil having a plurality of windings around the core, and an imaging element, and wherein the marker has a radiographic centroid and the alternating magnetic circuit has a magnetic centroid at least approximately coincident with the radiographic centroid.

50. The system of claim 40 wherein the marker comprises an alternating magnetic circuit having a ferrite core extending along a longitudinal axis, a coil having a plurality of windings around the ferrite core, and a capsule encasing the ferrite core and the coil, and wherein the ferrite core has a maximum cross-sectional dimension normal to the longitudinal axis of not greater than 0.7 mm and the capsule has a maximum cross-sectional dimension normal to the longitudinal axis of not greater than approximately 2 mm.

51. The system of claim 40 wherein:
the distal section of the tube has a wall with an inner surface defining the lumen and an outer surface; and
the transponder comprises a tubular ferrite core having an inner bore and a coil having a plurality of windings around the tubular ferrite core, and wherein a portion of the outer surface of the distal section is in the bore of the tubular ferrite core.

52. A method for guiding an instrument through a passageway in a patient, comprising:

passing an instrument through a passageway of a patient, the instrument having a tube with a distal end, a lumen through the distal end, and a marker at the distal end; and

tracking the instrument as it passes through the passageway by (a) wirelessly delivering a pulsed magnetic field to energize the marker, (b) wirelessly transmitting a pulsed location signal from the marker to a location outside the patient, (c) sensing the pulsed location signal at a sensor located outside the patient, and (d) periodically calculating a three-dimensional location of the marker in a reference frame; and

providing an output of the location of the marker in the reference frame at least every t_f second and within t_l second from sensing the pulsed location signal, wherein t_f and t_l are not greater than 1 second.

53. The method of claim 52 wherein t_f and t_l are from approximately 10 ms to approximately 500 ms.

54. The method of claim 52 wherein t_f and t_l are from approximately 20 ms to approximately 200 ms.

55. The method of claim 52 wherein t_f and t_l are from approximately 50 ms to approximately 200 ms.

56. The method of claim 52 wherein t_f and t_l are from approximately 50 ms to approximately 100 ms.

57. The method of claim 52 wherein providing an output of the location of the marker further comprises referencing the three-dimensional location of the marker with an image of the passageway through which the catheter is passing and displaying the location of the marker relative to the image of the passageway.

58. The method of claim 57, further comprising providing an indication of when the marker is within a desired range of a target site for the marker.

59. A method of tracking an instrument in a patient, comprising:
providing an instrument having a device marker configured to wirelessly transmit a location signal in response to a wirelessly transmitted excitation energy;
attaching reference markers to a patient, the reference markers being configured to transmit reference location signals in response to a wirelessly transmitted excitation energy;
obtaining a reference image of a target and the reference markers at an imaging site;
positioning the patient at a treatment site separate from the imaging site;
locating the reference markers and the device marker at the procedure site by energizing the markers using a non-ionizing wirelessly transmitted excitation energy; and
displaying a representation of a least a portion of the instrument relative to the target.

60. The method of claim 60 wherein the markers comprises a resonating magnetic circuit and the non-ionizing wirelessly transmitted excitation energy is an alternating magnetic field.